

Verification and Implementation of Operations Safety Controls for Flight Missions

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International Space Station (ISS) Safety & Mission Assurance (S&MA) Operations

Introduction

Approximately eleven years ago, the International Space Station (Figure 1) launched its first module from Russia, the Functional Cargo Block (FGB). Safety and Mission Assurance (S&MA) Operations (Ops) Engineers played an integral part of that endeavor by executing strict flight product verification as well as continued staffing of S&MA’s console in the Mission Evaluation Room (MER) for that flight mission. How were these engineers able to conduct such a complicated task? They conducted it based on product verification that consisted of ensuring that safety requirements were adequately contained in all flight products that affected crew safety. S&MA Ops Engineers apply both systems engineering and project management principles in order to gain an appropriate level of technical knowledge necessary to perform thorough reviews which cover the subsystem(s) affected. They also ensured that mission priorities were carried out with great detail and success.



Figure 1. The International Space Station as seen from Space Shuttle Endeavour on July 28, 2009 [2].

Prior to the system performing its function, the system engineering & project management processes begin with the “top-down development” of processes & phases to be applied to each project/flight/mission which are in-line with recommended practices [1, 3]. With approved/ established processes/phases the S&MA Ops Engineers perform “bottoms-up integration and verification” through use of the available resources to the appropriate level of technical depth during the respective timeframe allotted for each project/flight/mission. The system engineering process is used on each level with control gate (review) before proceeding to develop the next lower level of problem and solution descriptions. The output (requirements baseline) at each level is the input to start the next level (iteration). In some instances the S&MA Ops Engineer will perform reviews with customers and stakeholders to confirm the need and obtain concurrence on interim solutions. Reports & assessments continue to move up the management chain at successively bigger picture combinations of solutions (integration) that have been tested (verified).

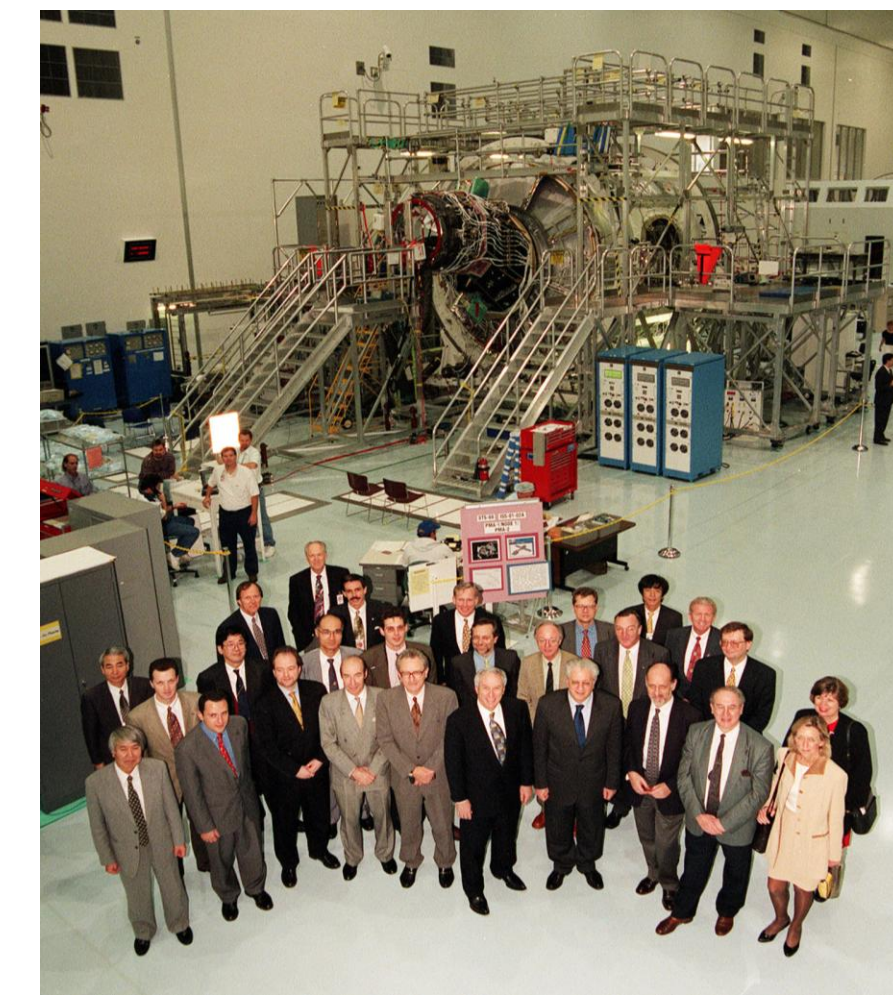
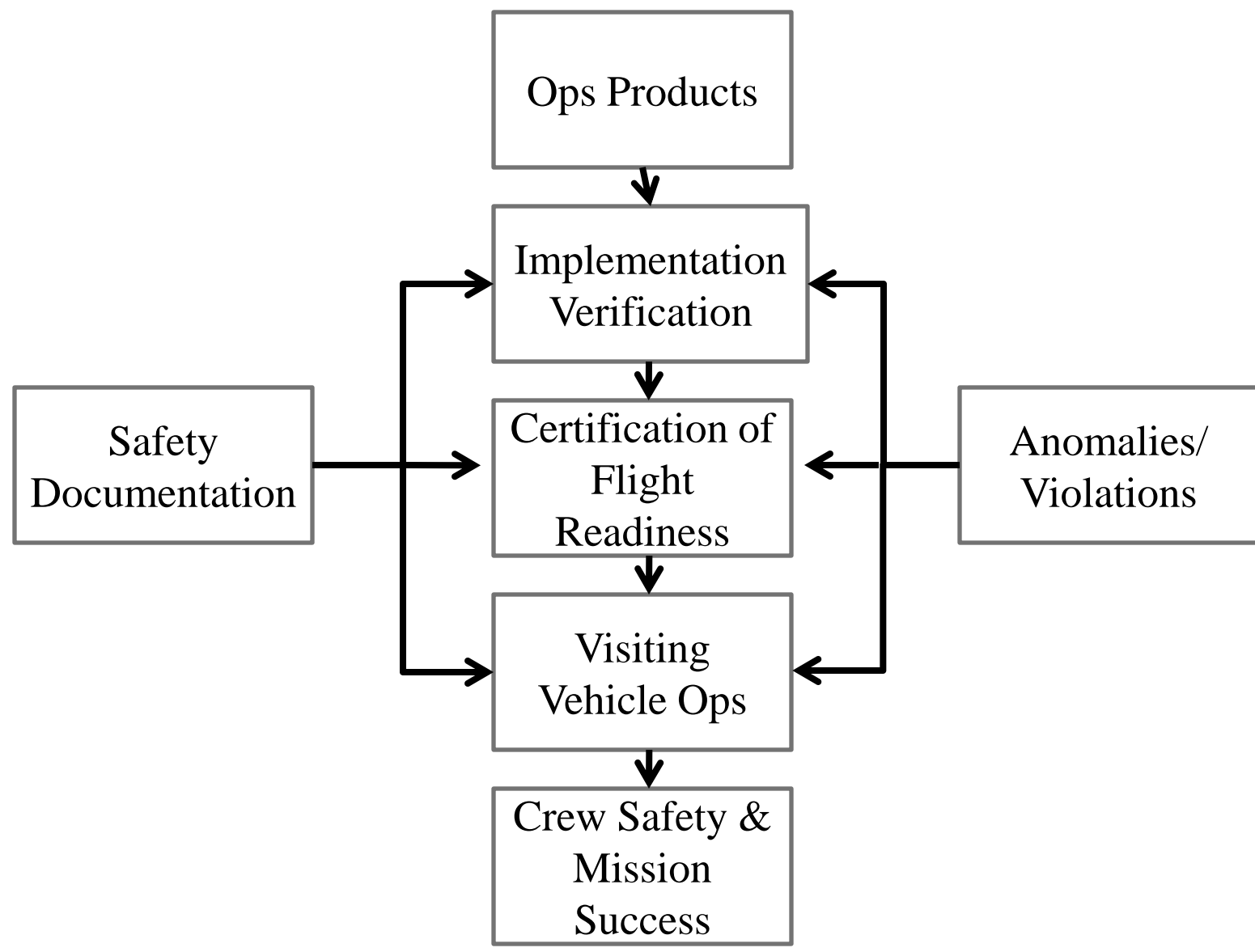


Figure 2. Senior government officials from 15 countries participating in the International Space Station signed agreements in Washington D.C. on Jan. 29, 1988 [2].

Safety and Flight/Mission Phases

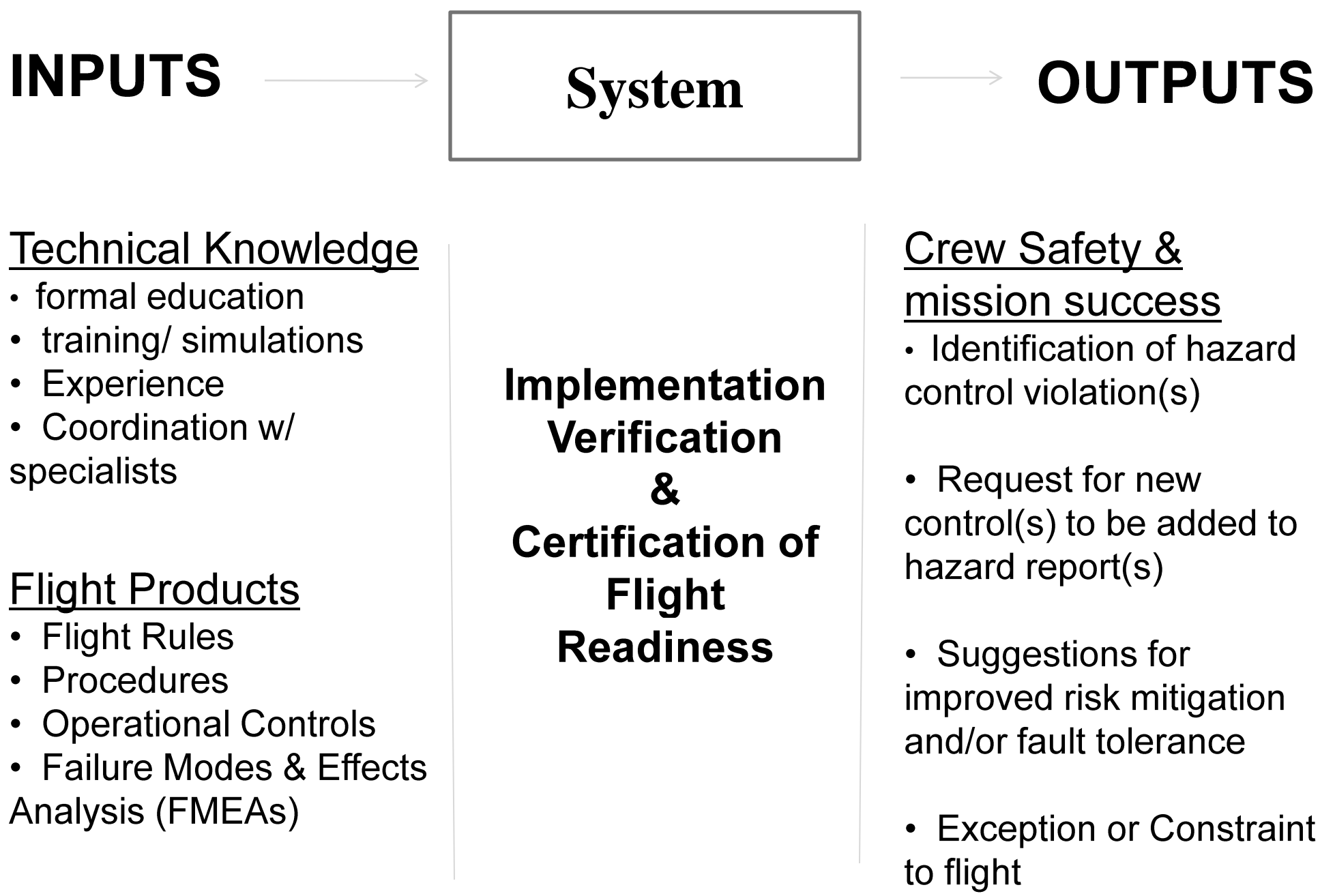
The INCOSE Handbook version 2a [1] defines Systems Engineering as the interdisciplinary approach and means to enable the realization of successful systems. There are several engineering disciplines such as: reliability, supportability, quality, human factors, risk management, safety, etc. Safety is an extremely important engineering specialty within the National Aeronautics and Space Administration (NASA) and a loss of crew is considered a catastrophic event. Safety is not difficult to achieve when properly integrated from the beginning of each space systems project/mission planning. The key is to ensure proper handling of safety verification throughout each flight/mission phase.



Implementation Verification

In order for any activity to materialize on orbit, it goes through a rigorous review process. S&MA’s initial involvement in this process is the implementation verification phase. Since hazards are common threats to the crewmembers on orbit, it is very important that flight products are adequately reviewed. Flight products consist of procedures and flight rules. Procedures are steps that instruct the crew on how to perform a specific task. Flight rules are directions to the Flight Control Team in Mission Control Center on how to get the vehicle (ISS, shuttle, etc.) in a safe posture. During this phase, S&MA verifies that any hazard controls associated with activities via flight products are properly implemented. In order to condense the quantity of risks exposed by the crewmembers, controls are put in place. Controls are defined as mitigation steps put in place to reduce risk. The Ops team ensures that hazard controls are implemented within all flight products with a direct impact on safety. With each product review, the Ops Engineers are able to provide an independent assessment on the validity of hazard control implementation. So how does S&MA perform these complex verifications successfully? Each Ops Engineer has to go through the following stages to perform these assessments properly:

1. Training
2. Tools
3. Feedback



Certification of Flight Readiness

Certification of Flight Readiness (CoFR) is an assessment process that ensures adequate certification for flight activities performed by the NASA program. This certification is based on the evaluation and disposition of various organizations’ endorsement codes. Endorsement codes are utilized within the CoFR process to show that open work has been examined, the endorsement guarantees that all obligated work has been performed, and a signature from the appropriate organization is then gained by the ISS Program Office. However, before an endorsement signature is obtained, an assessment is conducted to ensure that a successful mission is completed without much complication. As such, this assessment ensures operational readiness and the safety of the ISS on-orbit flight assembly operations. The assessment provides operations as well as other organizations with a look at open work that may impact the flight mission. Moreover, several organizations take part in this assessment to certify that tasks, activities, and products related to endorsement statements have been accomplished [4]. The following are important factors involved in Operations Safety Assessments:

1. Hazard
2. Controls
3. Weighing Risk
4. Mitigating Risk
5. Implementation



Figure 3. European Space Agency's “Jules Verne” Automated Transfer Vehicle (ATV), September 5, 2008 [2].

Visiting Vehicle Operations

Implementation Verification and CoFR are also performed for visiting vehicles with an additional step of observing export control laws. Russia, Canada, Europe and Japan are established international partners due to the presence of their module(s), equipment and/or personnel that has been on the ISS. The United States and our international partners have visiting vehicles that are used to transport/equip the ISS’s crew and to assemble/maintain the ISS. The United States and Russia have human space flight vehicles – Space Shuttle Orbiter and Soyuz (respectively). Russia, Europe and Japan have successfully launched and docked/berthed automated cargo transfer vehicles to the ISS (Figure 3). The United States is currently developing an automated transfer vehicle.

Summary

Unique flight tasks that are required before a flight/mission occurs serve to illustrate the vast complexity of the Implementation Verification, CoFR and Visiting Vehicle Operations phases. Moreover, because extensive reviews take place early on, along with in depth assessments being heavily embedded into flight products, several flight/missions appear to be performed without much complication. So in the public eye these tasks seem easy. However, though these tasks may seem to be conducted without complexity, several man-hours are poured into each flight product to ensure that tasks are performed correctly. For example, safety is a very important key aspect of these flight products and it greatly contributes to the reason that a flight/mission is carried out with great success. For instance, several phases and reviews are accomplished by several organizations that have a vested interest in the success of every flight/mission. These organizations have several experts that are able to provide technical input and they also heavily weigh into the flight products at the beginning of the flight/mission planning stages. These organizations are also key players at ensuring that flight/missions are accomplished without failure. Therefore, successful flight/missions are carried out by the assistance of several expert organizations along with various safety organizations and they are the key reason that complex tasks are performed with great success.

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